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SECTION OF GEOLOGY AND MINERALOGY[1]

APRIL 5, 1943

PROFESSOR WILLIAM A. LYNCH, Department of Physics, Fordham University, New York, N. Y.: *Deep-focus Earthquakes.* (This lecture was illustrated by lantern slides.)

INTRODUCTION

The subject of deep-focus earthquakes is introduced best by a brief consideration of normal or shallow earthquakes, which are simpler physically and seismologically. With information about normal earthquakes as a background, we can proceed to the characteristics of the deep shocks and complete the discussion by pointing out the importance of these quakes to physical and geological theory.

NORMAL EARTHQUAKES

Normal earthquakes occur at depths ranging from a few kilometers to about 50 km. below the surface of the earth, the average often being taken at 25 km. California shocks are very shallow, while those in Chile that are classed as normal are actually at about 50 km. Shallow earthquakes are characterized by an intense disturbance close to the epicenter (the point on the earth's surface vertically above the origin of the dis-

[1] The Section of Psychology met April 19, 1943. Doctor David Wechsler gave an address entitled, "Psychological Test Screening for the Emotionally Inadequate," and will submit an abstract later.

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turbance, or focus), the intensity diminishing as the distance increases from the epicenter. The probable immediate cause of the majority of normal earthquakes is slipping along a fault-plane, the earth rebounding elastically as the rupture along the plane occurs. In the San Francisco earthquake of 1906, displacements had been set up in opposite directions on either side of the San Andreas fault at distances up to five miles from the fault before the rupture occurred.

When such a disturbance originates in the elastic earth, waves of several different types travel outward with velocities determined by the kind of wave and the properties of the medium. The waves that travel through the body of the earth are of two types: compression-rarefaction waves, commonly called longitudinal, and distortional waves, commonly called transverse. The vibrations of the medium when a longitudinal wave passes are back and forth in the same direction in which the wave travels; sound waves are longitudinal. The vibrations of the medium are perpendicular to the direction of advance when a transverse wave passes; waves on a stretched string that is struck or plucked are transverse. The longitudinal wave travels faster through the earth than the transverse although both follow the same path between two points, say from focus to seismic station. As the depth increases, the velocity of each type of wave increases; hence the waves seek the greater depths and follow a curved path between the two points in order that the time of travel may be a minimum. The result is that the ray paths are concave upward. At the station, the longitudinal or P wave arrives first, followed by the transverse or S wave; the time interval between their arrivals is a measure of the distance from epicenter to station along the surface of the earth. Travel time curves have been plotted for these phases, that relate the S–P interval to the epicentral distance.

Surface waves are also generated by the disturbance. They travel at constant speed over the surface of the earth and penetrate only slightly below the surface. They are likewise of two types: the Love waves and the Rayleigh waves. The former are transverse waves that are confined largely to the surface layer; the particles of the medium vibrate horizontally only, as the waves pass. They travel more slowly than the S waves and are of greater wavelength. The Rayleigh waves are similar to water waves since the particles of the medium oscillate in vertical elliptical paths; the vibrations have no horizontal transverse component. These waves travel more slowly than the Love waves, have long wavelength, and die out exponentially with depth.

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DETECTION OF EARTHQUAKE WAVES

A seismic station detects these different waves by seismometers, which are usually pendulums mounted to respond to vertical motion or to horizontal motion. The P wave disturbs the vertical pendulum more than the horizontal because it pushes upward or pulls downward at the earth's surface as it emerges. The S wave on the other hand affects the horizontal pendulum more than the vertical because it shakes the surface from side to side. A well-equipped station has at least one three-component seismograph, consisting of a vertical seismometer and two horizontal seismometers, one mounted to detect east-west motion, the other north-south. When an earthquake occurs, the seismologist examines the vertical record for the onset of the P wave and the horizontals for the S; he thus obtains the S–P interval and the epicentral distance. If all three components record P clearly, he can tell the direction from which the shock arrived.

The Love waves consist of horizontal vibrations only and do not disturb the vertical pendulum. The Rayleigh waves have both vertical and horizontal vibrations and thus record on the vertical and horizontal seismometers. The three records serve to distinguish between Love waves and Rayleigh waves and to verify the direction of arrival of the disturbance. The times of arrival of Love and Rayleigh waves check the epicentral distance.

REFLECTED WAVES

The P and S waves suffer reflections just as do other forms of wave motion. For example, the vertical seismometer records a longitudinal wave following the first P wave, that has been reflected by the surface of the earth at a point midway between the epicenter and the station. It is known as PP; that is, a P wave that has been reflected once at the earth's surface. Similarly the horizontal seismometer records a transverse wave after the first S wave, that has followed the same path as PP; it is called SS. Earthquake waves have an additional property not possessed by sound and light; they may be transformed at the time of reflection. A longitudinal wave may be reflected as a transverse wave; it is then designated as PS. Similarly a transverse wave reflected as a longitudinal wave is called SP. Other possibilities arise such as PPS and SPS.

Suppose an earthquake occurs at a distance of 6000 km. We should expect to identify these phases on the records in the following

order: P, PP, PPP, S, PS, SS, SSS, the Love waves and finally the Rayleigh waves.

DEEP-FOCUS EARTHQUAKES

We are now ready to turn to deep-focus earthquakes. They are characterized by nearly uniform intensity over a large area in the vicinity of the epicenter. This becomes clear when we think of a focus at a depth of 200 km. A point on the surface of the earth 100 km. from the epicenter is only about 25 km. farther from the focus than the epicenter itself. A severe shock at this depth would affect a very large area, but the intensity near the epicenter would be small in comparison with that of a shallow shock of the same magnitude.

The records of deep-focus earthquakes differ from those of normal earthquakes in two important ways: the surface waves are weak or entirely absent; new phases make their appearance. The first property can be accounted for readily in terms of a reciprocal theorem in the mechanics of vibrations. In general, this states that if a variable force applied at one point in a system produces a certain effect at a second point, and is then transferred to apply at the second point, it will produce the same effect at the first point. We recall that surface waves in shallow quakes die out rapidly with depth; hence a disturbance at depth will produce little effect of this kind at the surface. Jeffreys has calculated the magnitude of the result and states that the records of quakes at depths greater than 150 km. should be practically free of surface waves. Very often a glance at the records is sufficient to establish the fact of abnormal depth.

The second characteristic requires more consideration. Suppose an earthquake occurs at a depth of 300 km. It sends out P and S waves that travel to a station by the path of shortest time as in normal shocks. It also sends out waves that are received as PP and SS after a single reflection at a point less than midway between epicenter and station. A third longitudinal wave leaves the focus in a direction such that it strikes the surface near the epicenter, is reflected and continues on to the station, where it arrives after P but before PP; this phase is designated pP, and is found regularly on the records of shocks that have abnormal depth. A third transverse wave behaves in the same manner, arrives after S but before SS and is called sS. The time interval pP–P, between the arrival of P and that of pP, increases rapidly as the depth of focus increases but changes only slowly with distance. It is the most important interval that we have for determining depth. The interval sS–S is a check on the results obtained by the use of pP–P.

Other phases occur such as sP and pS. The former starts as a transverse wave, is reflected at the surface near the epicenter, is transformed by the reflection and completes its journey to the seismic station as a longitudinal wave; the latter behaves in just the opposite fashion. Still others exist, for example sPP, sPS, sSP, pPS and so on. It is evident that the seismograms of deep shocks may be exceedingly complex.

To illustrate the magnitude of the time intervals involved, we may take the following from the tables of Gutenberg and Richter:

TABLE 1
DIFFERENCES IN TRAVEL TIMES, pP–P, IN MIN. : SEC.

Epicentral distance in degrees	Depth of focus in kilometers						
	100	200	300	400	500	600	700
50	0 : 26	0 : 45	1 : 05	1 : 21	1 : 36	1 : 50	2 : 03
60	0 : 25	0 : 47	1 : 07	1 : 25	1 : 41	1 : 55	2 : 08
70	0 : 25	0 : 48	1 : 10	1 : 29	1 : 47	2 : 02	2 : 15

TABLE 2
DIFFERENCES IN TRAVEL TIMES, sS–S, IN MIN. : SEC.

Epicentral distance in degrees	Depth of focus in kilometers						
	100	200	300	400	500	600	700
50	0 : 35	1 : 21	1 : 54	2 : 23	2 : 51	3 : 17	3 : 41
60	0 : 44	1 : 24	1 : 58	2 : 30	2 : 59	3 : 26	4 : 03
70	0 : 41	1 : 22	2 : 00	2 : 35	3 : 06	3 : 36	4 : 03

The seismograms of deep-focus earthquakes are clear and the time intervals are easily read as the phases have very sharp beginnings. This is particularly true of P, pP, S and sS, those phases that are most important. Distance is determined by the interval S–P but special travel time curves must be drawn for each depth. Gutenberg and Richter have made the calculations for depths from 100 km. to 800 km. for all the phases that are commonly recorded. In the seismological observatory we use at least nine charts of travel time curves: one for normal shocks and the others for the different depths from 100 km. to 800 km. by steps of 100 km.

DEEP-FOCUS EARTHQUAKES AND THE INTERIOR OF THE EARTH

The realization that deep-focus earthquakes do occur has opened up new avenues of approach to the study of the interior of the earth.

Phases that are recorded in normal earthquakes among the surface waves are difficult to isolate and identify because of the continued and vigorous disturbance in that part of the record. This is particularly true of certain phases reflected from the earth's core. The seismologist believes that about midway to the center of the earth there is a very definite discontinuity, a change in structure so marked that earthquake waves are reflected from it and are strongly refracted if they pass the boundary into the lower medium. Longitudinal waves are changed in velocity from about 13.8 km./sec. to 7.5 km./sec. as they enter the core. Transverse waves, however, appear not to pass through the core. This has led to the belief that the core is fluid, because it permits the passage of longitudinal waves but not of transverse waves. A longitudinal wave that strikes the core is partly reflected and partly transmitted. Let us follow the reflected phase. It travels a curved path up to the surface and is detected by a vertical seismometer as a P phase; but it arrives much later than the initial P, at the shorter epicentral distances. The time interval is about 4 minutes at 2000 km. This phase is called PcP, the c indicating that reflection occurs at the core. In normal earthquakes PcP is not very prominent and may be lost in the disturbance due to S on the record at small distances from the epicenter, and that due to the reflected waves PP and PPP at greater distances. In deep-focus quakes, it is often sharp and well-defined on the record. More important than PcP is the transverse wave, ScS, that behaves in a similar manner. It is more energetic, however, because transverse vibrations do not pass through the core and a larger fraction of the shear energy is reflected. It is recorded on the horizontal seismometer. At an epicentral distance of 2000 km., it arrives about 11 minutes after P in the midst of the surface waves if the earthquake is shallow, but in an undisturbed portion of the record if the shock is deep. The deep-focus records give us the opportunity of observing PcP and ScS and other waves similar to them such as PcS, ScP, pPcP and sScS. If these reflected waves are correctly identified and their travel times determined accurately, the distance to the core can be obtained. Jeffreys states that if the travel time of PcP is known to a second, the depth to the core can be found to within 7 km.; and if ScS is known to a second, the depth can be found to 4 km. This corresponds to a high degree of precision as the distance involved is about 3000 km. In order that the measurement may be successful, it is necessary to locate

the epicenter of the deep-focus shock precisely and to find its depth exactly. It is difficult to do both of these.

Let us follow that part of the longitudinal wave that entered the core. It is refracted as it enters, follows a curved path through the core, is refracted again as it emerges, and follows a final curved path to the surface. The symbol used for this phase is PKP or P′. The K indicates that this leg of the path is through the core, the disturbance travelling as a longitudinal wave. An S wave must be transformed into a longitudinal wave to be transmitted through the core. We find that phases such as SKP and SKS emerge on the far side. The former completes the final stage of its journey as a longitudinal while the latter reaches the surface as a transverse wave. These and still more complex combinations are found on the records of earthquakes at large epicentral distances. When the shocks are deep-seated, many more phases are present, such as pP′, sSKS, pSKP and so on. All of these are more sharply defined on the records of deep earthquakes than the corresponding phases of normal shocks. Their study gives us further information about the boundary of the core and the structure of its interior, for these waves are the most direct probes that we have of the interior of the earth. A complete interpretation of the seismograms of an earthquake at an epicentral distance of about 145° would give us a very detailed description of the properties of the interior of the earth.

MORE ABOUT THE INTERIOR OF THE EARTH

It is clear from the above statements that the seismologist is convinced that earthquakes occur at depths far below the surface. The estimated depth of the deepest thus far recorded is about 750 km. Conditions in this region must be entirely different from those where shallow earthquakes occur. However, the records of both normal and deep shocks are fundamentally the same. The differences are accounted for, not in terms of the physical properties of the interior at different levels, but largely in terms of the geometrical and mechanical changes produced by a change in level of the origin of the disturbance. The P phases and the S phases are vigorous and pronounced on the records of deep shocks; hence energy must have been stored in the forms of compressive strain and of torsional strain or shear. But is is believed by the isostasists that below about 100 km. the interior is in a plastic condition and inequalities of stress are relieved by slow plastic flow. An earthquake is a sudden fracture following a rapid building up of

stress that the slow process of plastic flow cannot relieve. The plastic material can store shear energy in spite of its fluid properties because of the high viscosity at great depths. Internal friction opposes relative motion of different layers until the limit of restraint is reached; and then a rupture occurs. Deep earthquakes occur periodically in the Hindu Kush Mountains. Instrumental observation places all of them at the same epicenter and depth, about 230 km. More than 40 have been recorded since 1907, many of them violent. The method by which the energy is renewed and stored is not clear as yet; but the mechanism of the earthquake itself seems to be the same as that of a normal shock, a slipping along a fault-plane.

Even though the material at depth in the mantle may be in a plastic condition, it can transmit transverse earthquake waves, for it behaves toward rapid vibrations as though it were an ordinary solid. Tar and sealing wax flow when left unsupported for a long time and yet vibrate transversely when struck. The element of time must be taken into account when investigating phenomena of this type, and further discussion of this aspect of the subject would take us too far afield.

DISTRIBUTION OF DEEP-FOCUS EARTHQUAKES

A second problem of major proportions for the geologist concerns the distribution of deep-focus earthquakes. A great belt encircling the Pacific Ocean is the locus of a great majority of the abnormal shocks. Two large gaps exist in this belt, however: one from Central Mexico to Alaska in which deep shocks are unknown, and the other from the vicinity of New Zealand to South America where seismic activity in general is relatively slight.

Along the belt where deep earthquakes occur, those of greatest depth are on the inland side, away from the Pacific. Shocks of intermediate depth are nearer the ocean, while the shallow earthquakes are along the coast or out in the sea. This type of distribution is prominent in South America. Epicenters of shocks from 600 km. to 660 km. depth lie east of the Andes with which they do not seem to be connected; those from 100 km. to 290 km. are mostly in the Andes; while the shallow quakes are close to the coast. Gutenberg and Richter state that they have found no South American shocks at depths between 290 km. and 600 km. The distribution of earthquakes at depth is complicated in the Japanese Islands and in the Dutch East Indies, but the general rule seems to hold throughout. Gutenberg is led to the conclusion that the

deep-focus belt marks the boundary between the two types of crustal structure, continental and Pacific.

The only zone of deep earthquakes outside of the circum-Pacific belt is that extending across Central Asia into Europe north of the Mediterranean. The greatest depth thus far recorded here is about 300 km. The Hindu Kush Mountains are in the zone, and the other seismic regions of the Himalayas. This zone also includes Rumania where shocks occur periodically at about 150 km., much as they do in the Hindu Kush. The most recent was the violent earthquake of November 1940.

CONCLUSION

An attempt has been made to summarize the principles of seismology with special reference to deep-focus earthquakes, and to point out some of the problems that have arisen as a result of the discovery that earthquakes do occur at great depths. Continued investigation of deep earthquakes is bound to lead to a better understanding of the interior of the earth. It is hoped that what has been presented here will aid those who wish to read further in the subject.

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SECTION OF BIOLOGY

April 12, 1943

Doctor Charles M. Breder, Jr., The New York Zoological Society, New York, N. Y.: *Problems in the Behavior and Evolution of a Species of Blind Cave Fish.* (This lecture was illustrated by motion pictures, lantern slides and living specimens.)

There are only twenty species of definitely blind and whitish cave fishes known, which number may be reducible to sixteen if broader specific definitions are employed. These are from widely separated localities. In addition there is about an equal number of forms with more or less defective eyes which are associated with caves or other cryptic types of environment,[10] exclusive of blind fishes of the oceanic depths.

Relatively few of the abyssal fishes are blind, and in this special situation optical stimulation is far from absent, since many species of abyssal fishes and invertebrates possess luminous organs which are evidently of considerable biological significance. On the other hand, the fresh water caves of the world present an optical void, for no light-giving structures have been developed by the aquatic inhabitants and, save for a relatively few rare items such as phosphorescent bacteria, cave waters are without light stimulation.

The sixteen genera of entirely blind cave fishes proper represent seven orders, distributed through nine families. The others, with more or less defective eyes, of which there are about an equal number of species in about twenty genera are nearly all more or less related to the true cave fishes, but grade off insensibly to normal types. However, in all of these groups not one blind cave fish is known to be genetically connected with its nearest non-blind surface relative, excluding only the case which is the subject of the present remarks.

In 1936 a new cave fish was described from Mexico by Hubbs and Innes. This fish they called *Anoptichthys jordani*, new species, new genus, which was described as differing from its nearest relative *Astyanax mexicanus* (Philippi) only in the absence of pigmentation and the absence of an eye.[11] Strictly taxonomic problems involved in this material will not be discussed at this time. Since the original discovery there have been three additional visits to this cave, which is known as La Cueva Chica, by American students; Dr. Myron Gordon in 1939, the New York

Zoological Society expedition[8] in 1940, and Mr. B. Dontzin,[2] for the Society in 1942. Cueva de los Sabinos, another cave about fifteen miles distant has yielded an undescribed form, slightly differing from the first, which was also found by one of Dr. Hubbs' collectors. Mr. Dontzin visited this other cave and brought back the first living specimens which are now under experimental study.*

These fishes differ from other known cave fish in a number of respects which make them especially suitable for experimental study and which led to the Society expeditions of 1940 and 1942. Some of the more striking of these features follow:

1. The La Cueva Chica fish apparently differs from the surface form only in lacking visual organs and pigmentation.
2. The group (Family Characidae) is one in which it would hardly be expected to find a blind offshoot, for they are types largely dependent on their eyes. Most other cave fishes have been derived from groups that already have marked tactile or other sensory developments in addition to sight.
3. They thrive well in ordinary warm aquaria of standing water. The caves which they inhabit are warm, an unusual circumstance, because caves are normally cold even in the tropics.

It was with these features in mind that the 1940 expedition was undertaken, in order that some understanding of the ecological background could be obtained for aid in connection with projected laboratory experiments. Although there was some slight variation in the fishes previously collected, their closely bred descendants in aquaria showed no greater variation. It remained for this party to uncover the fact that there was a complete intergradation from the outside river population to the fully blind and white cave form, which condition ran as a gradient from the river connection.[1] Many of these were brought back in a living condition and now form the basis of breeding experiments. It is too soon to say anything definitive regarding the genetics of the situation but it is evident that there are a considerable number of factors involved, the genotypic expression of which produces a population showing about every degree of intermediacy that could be expected, including all degrees of pigmentation, reduction of eye size and loss of parts of the eye, which features lack complete correlation. There are some specimens lacking pigment but having eyes, pigmented individuals without eyes, and even some unilaterally blind specimens.[1] It appears that the first generation of a cross between a white blind fish and an eyed pigmented fish all resemble the latter parent, but there is a peculiar

*The current laboratory work is being carried on in the Department of Animal Behavior of The American Museum of Natural History.

behavior item to be dealt with later that may vitiate this apparent result of tank breeding.

There is still another complicating item to be considered. The first pool in the cave that is encountered on entry has had four collections taken from it over a period of six years. The first two obtained only the blind white fish; the third, blind plus some intermediate fishes and a few with normal eyes; while the fourth obtained still more eyed intermediates and eyed forms with full pigmentation, a type not present in the first three. The situation thus stands with an increasing gradient in eye and pigment as the river is approached and an apparent similar gradient in time at the point most remote from the river. It would seem that here are two basic possibilities in regard to speciation.

1. That these populations have always been in contact and that various waves of migration inward by river fish give fluctuations over the years in the phenotypes found, some of which are truly invaders and some of which are the result of eyed and blind crosses, with a primary zone of intermediates.
2. That these populations have actually been separated by some barrier that has been recently removed and that the intermediates are the "hybrid" product of the merging populations, perhaps moving toward a swamping out of the smaller blind population, with a secondary zone of intermediates.[8]

Before one can attempt to evaluate these possibilities it is desirable to know something of the differential behavior of these fishes, which, as will be shown, has a considerable bearing on the possibilities involved. In order to undertake such experiments intelligently one must first have some understanding of the sensory characteristics of the river and cave fishes.

The eye of the river fish is the dominating sense organ as is indicated both by the behavior of the fish in its social life and feeding reactions, the structure of the eye and of the relatively great development of the optic lobes. The remnant eye of the blind form is a tiny bean-shaped capsule at the base of the eye socket composed of the heavily pigmented choroid. Within this are a few scattered retinal elements and a much reduced optic nerve.[9] Nevertheless, these fish are light-sensitive to a slight degree, as has been shown by work with a gradient trough. Extirpation of this capsule makes them completely indifferent to light, whereas formerly they were slightly but significantly negative to light. Large old specimens with a greater mass of tissue overlaying the capsule are less negative than small ones without such a depth of tissue covering the capsule. Specimens with deformed eyes, of whatever size, are not light negative in this sense, but if given the opportunity

will spend much time in the shelter of a rock or other object, peering out into the lighted area. These forms are easily identified in the living state by feeding experiments. Those which form a retinal image will strike accurately at falling particles of food very much after the manner of a trout. Those which cannot, on the slightest disturbance, will go to the bottom and perform circling movements of much vigor until they find the food. Those with an exposed retina will "jump" when a shadow is passed over them while those properly blind will not. This refers to fish that have been kept for long in light during the feeding tests.[3, 4, 5]

Here again a time element enters. All fish brought freshly from the cave act like the blind fish in regard to feeding. This has been checked twice, all forms from the cave performing circling movements for food finding for at least a couple of months and then those with structurally good eyes apparently learning the meaning of a retinal image and taking on the feeding habits of the river fish. These forms at all times, from the first, "jump" at the passage of a shadow, like those with merely an exposed retina.

Simple observation indicates that these fish are very sensitive to mechanical disturbance and probably true sound waves. One of the easiest ways to catch them in the cave was to drop small objects in the water, about which they would gather even from a considerable distance. In deep water the gathering would be near the surface where the splash was made and not on the bottom. In captivity they could be "called" from inside an artificial cave by waving a finger in the outside water. Anatomical examination shows that the ears are degenerating but not as markedly as in the case of the eyes.[12] There is no evident hypertrophy of the lateral line system, but work on both these items is not yet sufficiently advanced to be able to say anything definitive. There is, however, no evident distance perception of obstacles as reported for other species of cave fishes. Placed in a strange environment they freely "stumble" into obstructions. In a short time they seem to learn the location of such objects by trial and error and from then on avoid them. Changing the position of a rock, however, will force the fish to learn all over again. A changeable obstacle such as the dangling legs of a large frog always gives them trouble. In an outdoor pool which was inhabited by several bullfrogs, some would collide with the feet of the latter continually, with the result that they would charge off at random and take some time to find themselves, again colliding

with all manner of permanent and familiar fixtures.[6] While they do sometimes strike one another, it seems that the swimming activity of the other fish gives them some warning to turn.

The great number of replacement scales found on the wild fish indicates that they normally lose many more scales than do fishes in general. Many of the larger fish have very few of their original scales. These losses presumably occur when, for some reason, they are frightened out of their own territory or perhaps washed out when there are freshets.[1]

The chemical senses are apparently normally developed in these fish, but do not seem to be hypertrophied. They show positive and negative reactions similar to those of various surface fishes.[7] Food is no problem to these fish because of the presence of insectiverous bats. Examination of the stomach contents showed that the food consisted entirely of bat droppings and the eggs of each other. Bat droppings are continually supplied and contain a rich fauna of some macroscopic nematode. This is supplemented by an occasional dead bat. That the eyed river fish are able to survive in this same situation is evident from the condition of those found in the cave and the fact that they live well under not dissimilar conditions in captivity. Their food requirements are simple and there is as yet no reason to suppose that there has been any improvement in their chemical sensory development. Histological examination shows no significant structural modifications in the fish from either cave.[7]

Thus, as far as present evidence goes, at least, we have a case of an intrusion into a "simpler" environment with a loss of sensory refinements but with no evident substitute structural developments. It suggests rather an analogy to a trematode living in a mammalian gut than to what has been reported for other cave fishes. Food is extremely abundant, predaceous enemies are evidently absent and reproduction would seem to be the prime concern. Before considering that, however, a brief review of the social aspects of blindness in these fishes should be made.

The normal-eyed river fish are strongly gregarious and when there is no special external stimulus they rest in a closely compact school all facing the same way, which is apparently disrupted only by fright, food or reproductive activity.[3] This gregarious habit, so far as known, is inspired by visual perception. The blind fish do not form schools but wander continually at random, as would be expected. This wan-

dering movement is apparently kept up at practically all times and has been shown experimentally to be truly at random and without reference to other individuals. Incidentally, the blind fish eat much more than the eyed ones, which may have to do with the extra energy expended in their continual wandering. Blind and eyed fish placed together for the purpose of cross breeding present a bothersome problem. The eyed member attempts to follow the blind one in its aimless wandering. This very often results in disaster for one or the other, because:

1. The eyed fish may become emaciated and eventually die.
2. The eyed fish may become erratic in behavior. One actually took to spinning on its snout at one end of the tank, but recovered after removal.
3. Most likely the eyed will attack the blind and destroy it.
4. An accommodation may be made and the eyed fish subsequently pay little heed to the wandering of the blind.

This kind of behavior in light may well result in the survival of eyed forms only from a mixed spawning, which could easily lead to an erroneous genetic interpretation. This feature has not been adequately checked as yet.

Reproduction in the river fish is of the simplest sort; the pairing and courting consists of chasing by the male, circling by both fishes and finally the ejection of eggs and sperm while the fishes take a side-to-side position. This item of behavior is evidently entirely visual. Blind fish, apparently little aware of each other, when in the proper physiological state, increase the rate of their "random" movements far beyond the normal speed. They are not so apt as usual to turn aside from one another and collisions are more frequent. In short they do exactly what one would expect a blind fish to do. They circle and gyrate about as the crucial time approaches but continually "lose" one another. In one case a female cutting small circles at one end of the tank discharged her spawn while the male was wildly dashing up and down the glass at the far end. Nevertheless the eggs hatched, for in spite of this distance they were fertilized. It might be objected that this was a special case in a small aquarium and would not take place in nature. It must be called to mind that many of these fishes are living in small calcium cups in the flow-stone of the cave which are not materially larger than a moderate sized aquarium. Further, due to the nature of such caves there are countless ways in which groups may be trapped in small quarters and it is possible that here only is successful spawning attained.

The normal river fish are very positively rheotropic and will follow up the slightest flow. Since the water leaves this cave to empty into the

river this is one likely cause of original entry. Further, it has been shown that as slight a differential as 1.5° F. will cause eyed and blind alike to enter or leave an artificial cave independent of the presence or absence of light outside, and subsequent work indicates this reaction may follow on an even smaller thermal difference.[5] Since frequently the cave waters are somewhat higher in temperature than the river this is certainly another cause of entry.

With a cave constituted as is La Cueva Chica, with outflowing water heated from below and warmer than the surface water for at least part of the year, and fish impelled to enter dark places and move upstream it is easy to see that under such influences the initial behavior of the fishes should lead to cave entry. Once inside they would have difficulty getting out, for when far enough in to lose the guiding influence of daylight they would have to reverse their normal rheotropism to come out in the open again. The onset of nightfall would also cause many to lose their return route. In this connection it should be remembered that nocturnal animals, on a clouded night, are voluntarily active under conditions similar to those permanent to a cave.

These river fish have a widespread constitutional variation in eye size. Locally it is possible that this might be interpreted as a genetic contamination from the cave population, but elsewhere this is not likely to be the case. Dr. Hubbs assures me on the basis of taxonomic measurements throughout the range of these fishes that it is widespread.

As the initial cave population would presumably be relatively small, it is not surprising that eye defects would be preserved and spread. The large amount of predation in the river would certainly not permit the establishment of a serious eye defect outside the cave. The gradient in the cave population as found would become clear on such a hypothesis, as there would be a continual infiltration of the river fish into the cave on a basis of their known tropisms. Movement back to the river of even the optically sound elements of the population would surely result in them being lost before they could learn the significance of a retinal image.

These are all, of course, negative elements in that they simply permit the continuation of defects but in themselves do nothing to suggest the selective elimination of the eyed fish within the cave. It may be that there is such a process in progress based on a possible psychic difference between a fish with good eyes living in darkness and one without such optical equipment. However, blinded river fish behave in a manner indistinguishable from those born blind.[7] The new form from

Cueva de los Sabinos, which has yielded no intermediates, differs principally from the other in the further progress in the same direction. These fish are more nearly transparent and consequently more pinkish in color and the internal anatomy is more evident. The choroid capsule of the other form is represented by some scattered pigment, but there are no retinal elements and the optic nerve is absent.[6] The shape of the mouth is slightly broader, the only evident difference so far noted not apparently clearly associated with a reduction of refinements. These fish also have a distinctly shallower nasal pit, the possible significance of which is not clear at this writing. Obviously it will be of considerable interest to determine if this population is homozygous for eye defect and associated items.

Whether the Cueva de los Sabinos stock is in contact with another form, eyed or blind, is a question that calls for more field work, as the cave is large and not thoroughly explored. In the meantime, laboratory experiments are under way to determine what behavior elements differentiate it from the La Cueva Chica material. So far it has been shown that there is no light sensitivity in this form, as would be expected with the elimination of the eye capsule.[6]

Given such a river species, with the described habits and carrying an eye irregularity, this kind of evolution could have conceivably taken place many times and it may well be that these two blind populations are independent developments from the same basic stock and differ only in the accidental assortment of genotypes that gave rise to them. Evidently the very marked difference in the behavior patterns of the eyed river fish and the blind forms is directly referable to the presence or absence of vision as has been shown by the immediate change to the "normal" blind behavior of freshly blinded specimens.

The question of the establishment of an apparently pure stock in Cueva de los Sabinos would seem to call for some as yet unknown selective process. The populations are no doubt comparatively small with breeding confined to limited colonies but, since the genic constitution is surely complex, it is hard to imagine that on such basis alone the intermediates could be fully eliminated.

An interesting speculation on the possible mathematics of the genetic reduction of other than blind white forms coupled with the repeated separation of small groups within a cave is discussed by Hubbs.[10] Actually, the geological separations found in La Cueva Chica could supply such a physical condition, as already noted, and the observed

gradient from the river could be supposed to rest on such a basis. In any case it should be evident that this material provides inviting problems both for the laboratory and the field.

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SECTION OF ANTHROPOLOGY

April 26, 1943

Doctor Margaret Mead, Associate Curator of Anthropology, The American Museum of Natural History, New York, N. Y.; Executive Secretary, National Research Council, Washington, D. C.: *Anthropological Approach to Dietary Problems.*

During the last year this section of the Academy has been devoted to discussions of the abstract contribution to be made to cultural anthropology from other sciences. There has furthermore been an attempt to relate the discussions to problems of immediate practical interest of war and post-war operations. Such an inquiry leads naturally to a consideration of the way in which the development of better abstractions will make it possible to employ coordinately the techniques of one or more scientific disciplines besides anthropology to the solution of a problem.

Diet is one of the fields which is particularly crucial to the war and the future successful organization of society on a world scale. Furthermore, it is a field where the findings from the natural sciences are susceptible to an integrated cross-disciplinary approach at two points: (1) the findings of soil chemistry, food chemistry, and the physiological study of nutritional status, and (2) the findings of psychosomatic studies, particularly in those disease pictures which involve the gastro-intestinal tract. At perhaps no other point of contemporary scientific attack on the problem of social change do we have available so many of the necessary techniques, which in the matter of diet include: techniques for assaying and supplementing the contribution of the physical environment and improving the stock of domestic plants and animals; techniques for assaying the nutritional content of the plant stuffs and animal products; methods of describing and analyzing the culture that patterns the way in which man uses this physical environment, determines his selection of foods and his methods of preparation and consumption; methods of studying the developing child so as to understand the way in which hunger is transformed into appetite by the systematic inculcation of attitudes toward food and own body; techniques for assaying the use which the human body makes of the food which is consumed; methods derived from clinical psychology and psychiatry for exploring the dynamics of food acceptances, rejections and symbolisms through the study of the psychopathology of gastro-intestinal diseases.

The satisfactory integration of all of these disciplines depends upon (1) an adequate conceptual scheme which will place each contribution exactly in the total context and (2) the state of the techniques in each of the cooperating fields.

In considering the techniques, it is valuable also to distinguish between the state of development of analytic techniques at a merely descriptive level, and the development of methods of using these techniques for controlled change. For example, soil analysis is very far along in the determination of the chemical content of the soil, quite far along in methods of supplementing or correcting that content for deficiencies or stepping up potentialities so that there will be an improved crop yield, when yield is considered in terms of volume per acre or when such factors as viability under adverse weather conditions, differential growth of grain and straw, storage quality of grain, etc., are considered. In the cases where alterations in the content of the soil are made to alter the quality of the meat from cattle pastured or fed from the products of that soil, there has also been a considerable technical development, with the emphasis, however, on quality values in the meat which are not necessarily related to nutrition. But in the field of relating soil composition and problems of supplementing or exploiting the qualities of the soil so as to produce food, either plant food directly or animal foods through the feeding of livestock, so that the food will have the highest nutritional yield, there is as yet only a beginning. The techniques are available but the details of application have to be worked out. When it comes to a question of adjusting the soil potentialities, as expressed in plant foods and in livestock feeding and poultry raising, so as to produce a completely adequate diet from a given geographical region, the problem has hardly been tackled and the techniques for a coordination of the relationship between the soil, the methods of soil supplementation and the nutritional content of the food so produced are in their infancy. But what is lacking is not a technique for assaying the food composition of carrots grown on a certain kind of soil, nor do we lack quick methods of mapping soil composition. The mere recognition by those who are planning a scientific attack on the problem of diet of the importance of integrating these existing techniques will be sufficient to bring them all into a coordinated relationship.

At this level however, there are a large number of cultural factors to be considered, varying from traditional patterns of land ownership, inheritance, tenancy, etc., through traditional methods of planting,

cultivation, rotation, stock feeding, choice of money crops, methods of marketing, export and import of foods into a given area, etc., which must be taken into account in determining how a living population's habits of food production and gross food utilization can be fitted together with the maximum utilization of the particular composition of the local soils. Furthermore, this problem ramifies from problems of land use on a given farm, where traditional crop choices or patterns of location of the garden may have to be altered to fit the realities of soil composition, through problems of national, continental, and finally global alterations of existing food production habits so that each area yields not only that food which under existing circumstances can be produced for a profit, but that which actually makes the best use of its soil and water conditions, so that the population of each area of the world may be adequately nourished.

It is wholly probable that states of malnutrition may be produced at any time through a shift in the traditional composition of imported and locally grown foods; but it is theoretically conceivable, especially in the case of the rarer mineral constituents of the diet that the substitution of the same food, grown on soil which produces an inferior product, may throw an entire diet out of proportion. There is also a problem of balance in planning social change. To what extent should a pattern which involves alteration in basic cultural habits be based upon a combination of economic, agronomic and nutritional thinking, which it then becomes the task of the cultural anthropologist merely to implement? How much responsibility should the cultural anthropologist assume for outlining the profound repercussions which a fundamental alteration of food production habits may have on the total culture and on the character structure of those who embody that culture?

What may be said of alterations in the field of production and distribution applies with equal force to the whole problem of food selection and consumption at the household level. The scientific techniques are being rapidly developed to evaluate the results of different sorts of storage, preparation and serving procedures, and are of course already available on the subject of balance of meals over time for different age levels and different types of occupation. These will of course be altered as knowledge increases, but enough is known to reveal a profound discrepancy between current practices and the fullest utilization of available foodstuffs for the nutrition of the family.

Historically the social sciences have been looked to as a sort of

super-propaganda agency; nutritionists have tended to ask from the social scientists: How do we put this across? What techniques will be most useful in getting people to drink more milk, or eat more oranges?

A complete anthropological approach will take into account: the way in which those things that are considered to be food are distinguished from those edible objects that are not regarded as food; the development of culturally sanctioned acceptances and rejections; the way in which food and feeding situations are used as potent instrumentalities for personality development; the integration of food behavior with other types of behavior such as sex behavior; the role that food choices may play in the development of conscience, of caste and class feeling, etc. That is, between the operation of the food production pattern, itself part of the culture, and the results which can be determined by a nutritional assay of the individual, the cultural anthropologist must interpolate an understanding of the role food plays in the system of interpersonal communication between the members of a society and each newborn member. Only if the place of food in a culture is accurately described and evaluated can the anthropologist perform either of the two functions discussed above, that of implementing a process of change and that of giving a critical estimate of just what the impact of any change in food patterns will be.

If adequate insight is to be gained into the dynamics of the ordinary character structure of the culture and the role that food plays, then the anthropologist can find much help in the findings of psychosomatic medicine, which will simultaneously illuminate the more typical character structure—in regard to food—and also, in the studies of deviant individuals. Deviant characteristics can be used to interpret the more frequent types of behavior. The regular patterns of distribution of succoring and dependence between males and females, or the extent to which a meal with a climax in which the end is the reward for having eaten the beginning becomes part of the typical conscience structure of members of a given culture, can be given additional force if we have detailed case studies of the mechanisms involved.

To the extent that the anthropologist is asked to assist in bringing about purposeful change in the behavior of a people in regard to food, whether it be production, distribution or consumption, it is necessary to know the way in which the desirable changes of habits are related to the entire system of behaviors that constitute the developed cultural personality. It is not sufficient for the anthropologist to provide the

techniques by which people can be persuaded to eat more bread or less meat, plant gardens, or cook their vegetables for a shorter period. Alterations in the dietary practices of a people involve alterations in their whole behavior and may disturb the whole pattern of individual responsibility, destroy the sanctions upon which parental authority is based, or alter a capacity for cooperative behavior. It is therefore the task of cultural anthropology to provide this part of the conceptual scheme within which the various natural sciences concerned with soil, food composition and nutrition, can operate with due regard for the unitary character of human culture, informed at every step of the possible consequences of the changes they wish to bring about. The simple maxim that people are inevitably better off if they have a better diet has to be qualified by a recognition that the means taken to reorganize patterns of behavior so that the better diet is possible may themselves be either constructive or destructive and outweigh in importance any dietary change short of an exterminating famine.

Anthropological techniques are already available for giving a thorough description of the integration of food in any culture, and on the basis of this description, for providing help in altering the food pattern and cautions about the results of such alteration. Less well developed, however, are the techniques for setting in motion within a culture a type of cultural behavior which is itself a form of prospective adaptation to change. It would be comparatively easy to introduce orange juice finally into the meal pattern of every American; it is more difficult to educate every American so that twenty years later whatever vitamin C carrier is recommended will be introduced in the diet, with sufficient flexibility so that orange juice may be displaced. In applying anthropology to problems set by government, the usual assumption has been that the answer was already known. It was desirable that natives should wash their clothes or use latrines or grow some supplementary vegetables, while they abandoned head hunting and other socially unacceptable practices. The food sciences themselves, however, are in a state of development and any rigid adjustment of whole cultures to present procedures or present knowledge would be most unfortunate. The problem for the anthropologist therefore is to devise methods by which an expectation that dietary patterns will change can be combined with a widespread acceptance of existing best practice.

Historically the rationalization, that is, the application of science to some area of human life which had formerly been governed by tradi-

tion, has brought about profound disorganization with exceedingly heavy consequences in human maladjustment. The necessary knowledge combined with the impulse to alter dietary practices comes at a stage when anthropology should be able to participate effectively in planned social change so as to obviate this disorganization and develop a style of procedure which may subsequently be applied to other fields as the techniques necessary become progressively available.

SECTION OF PHYSICS AND CHEMISTRY

April 16 and 17, 1943

Conference on *"Sulfonamides."*

The Section of Physics and Chemistry held a Conference on "Sulfonamides," as the fourth in the series for the Academic Year of 1942–1943. Doctor Colin M. McLeod, New York University, College of Medicine, New York, N. Y., was the Conference Chairman in charge of the meeting.

The program consisted of the following papers:

"A Theory of the Relation of Structure to Activity of Sulfonilamide Type Compounds"—

A. "Biological and Organic Chemical Aspects," by Richard O. Roblin, Jr., American Cyanamid Company, Stamford, Conn.

B. "Physical and Structural Aspects," by Paul H. Bell, American Cyanamid Company, Stamford, Conn.

"Relation between Chemical Structure and Physiological Disposition of Sulfonamides," by James A. Shannon, New York University, College of Medicine, New York, N. Y.

"Toxic Action of Sulfonamides," by H. B. van Dyke, the Squibb Institute for Medical Research, New Brunswick, N. J.

"Antagonists (other than *p*-aminobenzoic-acid) and Potentiators of the Sulfonamides," by Henry I. Kohn, Duke University, School of Medicine, Durham, N. C.

"The Action of Sulfonamides in the Body," by John S. Lockwood, University of Pennsylvania, School of Medicine, Philadelphia, Pa.

ANNOUNCEMENT OF PUBLICATIONS FOR 1943[1]

The following publications will be issued by the Academy during the current year. Members of the Academy who desire to receive these papers will kindly request the Executive Secretary to send them, and they will be mailed, free of charge, as they are ready for distribution, except as qualified in the footnotes:[2]

ANNALS:

1. "Boundary Layer Problems of the Atmosphere and Ocean." Papers delivered at the conference by this title. (Approximately 110 pages.)
2. "Criteria of Subspecies, Species and Genera of the Vertebrates." Papers delivered at the Symposium on Speciation, joint Annual Meeting of the American Society of Mammalogists and American Society of Ichthyologists and Herpetologists, March 31–April 2, 1942. (Approximately 80 pages.)
3. "High Polymers." Papers delivered at the conference of this title. (Approximately 150 pages.)
4. "New Methods in Stellar Dynamics," by S. Chandrasekhar. Awarded an A. Cressy Morrison Prize, 1943. (Approximately 30 pages.)
5. "The Relation Between Centriole and Centromere in Atypical Spermatogenesis of Viviparid Snails," by Arthur W. and Priscilla F. Pollister. Received Honorable Mention, A. Cressy Morrison Prize Competition, 1942. (Approximately 50 pages.)
6. "Studies on Fresh Water Bryozoa, XIV. The Occurrence of *Stolella indica* in North America," by Mary D. Rogick. (Approximately 16–20 pages.)
7. "Lycaenidae of the Antilles," by William P. Comstock and E. Irving Huntington. (Approximately 60 pages.)
8. "Parasitic Diseases and American Participation in the War." Papers delivered at the conference by this title. (Approximately 60–70 pages.)
9. "Color Constitution and Reactions of Dyes." Papers delivered at the conference by this title. (To be published later.)

TRANSACTIONS:

Series II, Volume 5, Nos. 1–8. These papers are sent to all members of the Academy, regularly, during the academic year. (Approximately 200 pages.)

[1] Notice of additional publications to be added to this list will be sent to members later.

[2] Active, Sustaining, Life, and Honorary Members may receive, upon request, a copy of all current numbers of the Annals.

Student and Associate Members are entitled to receive one complete monograph or up to 150 pages of smaller papers.

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Elected April 22, 1943

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